METEORIC AND TERRESTRIAL ROCKS.

AN unavoidable delay in the completion of the plates of a work to be published in the memoirs of the Museum of comparative zoölogy has rendered it advisable to publish in advance a brief abstract of some of the results thus far obtained. The work will contain descriptions of the microscopic characters of meteorites and the allied rocks; their classification; collected and arranged chemical analyses; a discussion of the principles of classification; the origin of rocks; the present and past state of the earth in its bearings upon petrography, etc.

The previous delays in the publication of this work have been owing to other labors, a change of plan greatly extending its scope, and the fact that work of the proposed character is vastly more difficult than simply 'pigeon-holing' rocks in different species, according to the minerals they happen to contain.

The results which it is desired to present here are as follows: —

1. Petrographical research demands a former liquid globe, and one whose interior portions are either now liquid, or in such a condition that they can readily become so.

2. That the interior of the earth is now probably liquid, is shown not only from petrographical and geological research, but also by the fact that the best and more recent observations either prove or render it probable that iron and such rock materials as are believed to compose the *infra*-sedimentary portion of the earth are lighter when hot-solid, at or near the melting point, than they are at about the same temperature when liquefied. Hence, according to Thomson's law, pressure lowers their fusing point, instead of raising it.

3. No sinking of the earth's crust to the centre could take place; for, since the interior is heterogeneous, the crust on sinking would meet with material of higher specific gravity, the heat imparted to the sinking matter would cause it to grow lighter, and the viscosity of the material still liquid would retard its descent.

4. All so-called physical and mathematical demonstrations of the earth's solidity have been based on certain hypothetical globes of unlike constitution with the earth; and hence have not the slightest application to it, but to the hypothetical globes only.

5. All rocks originally came from the cooling molten material of the globe, and the chemical and sedimentary rocks have resulted from the disintegration of that material.

6. All eruptive or volcanic (including plutonic) rocks were derived from material which either had never solidified, or had been reliquefied; but they were not derived from sedimentary or chemical deposits.

7. In the shrinkage and fracturing of the earth's crust, the depression of any portion into the still molten interior would naturally displace and cause the heavier liquid to overflow, just as the fracturing and depression of ice causes the heavier water to overflow it.

8. Water is the accident of an eruption, and is not the cause. It is met by the lava on its way to the surface, but is not the cause of the advance towards that surface. Hence it is probable that explosive volcanic action has become more common in recent times, while quiet outflows were more abundant in past ages.

9. Regions of crystalline rocks are, as a rule, regions in which eruptive, or mixed eruptive and sedimentary, agencies have prevailed, and are of every geological age, — meaning, by eruptive agencies, the original and secondary results of a cooling globe, including thermal waters. Metamorphism is even more common in eruptive than in sedimentary rocks.

10. The original rock-materials of the universe are the same, from whatsoever region they come, and the same principles should be employed in classifying them; while the classification, to be natural, ought to express their relationships.

11. A natural classification of rocks should be based on all their characters taken as a whole. It must be an empirical one, as in zoölogy and botany; and ascertained by studying all known forms, and arranging them according to their petrological, lithological, and chemical characters, — taking the rocks as a whole, and considering all their relations.

12. The present received classifications of rocks are artificial, based on part of the characters to the exclusion of others; they correspond to the Linnean artificial botanical classification, and hold about the same relations to a natural classification of rocks as that does to the natural classification of plants.

13. The great mass of rocks separated from one another as distinct species in these classifications are mere varietal forms of certain definite natural species, — the variation owing to alteration, or to some little change in conditions.

Distinction should be made between superficial weathering and the chemical and molecular changes that go on in all eruptive rocks after

consolidation and exposure to the action of infiltrating waters: that is, changes in the rock-mass as a whole; a change from an unstable to a more stable condition, — a loss of energy.

14. The original or eruptive rocks of the universe form a continuous series from the most basic to the most acidic; but for convenience they are to be divided into definite species or groups.

15. The preponderance of characters, and not the presence or absence of any one mineral, ought to decide the place of any rock in the system, yet the latter is the fundamental basis of the received lithological classifications. The original characters of the rock ought to hold priority in classification over any secondary characters.

16. Geological age has no bearing on classification, beyond this: that the older the same rock is, under like conditions, the greater is its alteration. The greater number of the so-called rock-species of pre-tertiary age are the altered forms of rocks which were once identical with tertiary and modern rocks.

17. A natural classification, in its broader applications, can be employed in the field as well as in the laboratory; for, as a rule, all the characters of rocks are so related to one another, that from one set the others can be inferred with a fair degree of accuracy.

18. When complete (*bausch*) analyses are made of typical rocks, rock-species are believed to have in their broader features certain limits of chemical composition outside of which the normal forms rarely go, and inside of which the normal forms of other species rarely come; but the mineralogical composition is more or less unstable and variable, depending upon alteration and other conditions to which the rock has been subjected. The chemical relations of rocks would be much better shown if the percentages were expressed in terms of the elements, instead of their compounds.

19. All rocks, except meteoritic and recent volcanic ones, are more or less altered; and it is from these altered rocks that the received classifications and the principles of classification have been chiefly based in Europe, — unaltered rocks being apparently limited there to the few active volcanoes.

20. Fragmental or derived rocks should be classed, as far as possible, under the rocks from which they were derived.

21. The relation of a rock to its associated rocks in the field is the principal criterion for determining its origin. This is especially the case in the altered rocks.

As examples of my meaning, it may be pointed out that the gabbros are here regarded as basaltic rocks lying near the peridotites; melaphyrs and diabases are principally altered basalts, but some rocks so classed are altered andesites; the porphyrites, principally altered and older andesites, but part are more acidic rocks; the propylites, with few exceptions, are andesites which are less altered and younger than the porphyrites; diorites, more or less altered forms of basalts, andesites, etc.; the quartz porphyries and felsites, principally old rhyolites; the nevadite is largely a vitreous rock, and belongs rather with the trachytes than with the rhyolites; kersanton, to the gabbros; minette, partly to the basalts and partly to more acidic rocks; the augite porphyries, partly to the basalts and partly to the andesites; the phonolites, partly to the trachytes, and partly to the andesites; and so on. Many schistose rocks are also formed by the alteration of eruptive rocks.

The position to which any rock should be assigned depends upon its affinities; and, in the above, the determination is based on such specimens as have been seen, which had been named by other lithologists. It is not intended to claim that every rock called by a particular name belongs in the position here assigned that name.

In applying the principles and methods given here, in the bulletin of the Museum of comparative zoölogy, and in the proceedings of the Boston society of natural history, the writer has been led to classify the meteorites and the large but comparatively unknown series of terrestrial rocks that are more basic than the basalts, as follows: —

1. *Siderolite.* — In this species or group are included a series of rocks composed chiefly of iron, either native or in its secondary states, with or without nickel, schreibersite, pyrrhotite, graphite, etc. It includes all masses of iron or iron-ore that have fallen as meteorites, those that can be shown to be original or eruptive portions of the earth, or directly derived from them; i.e., fragmental deposits. No veins or chemical deposits of iron-ore are included. The analyses of this species are imperfect; for they do not, as a rule, convey an idea of the composition of the rock-mass, but rather of the component minerals, especially of the iron. It is much as if a chemist should analyze magnetite from basalt, granite, and rhyolite, and then consider his analyses as typical of the rocks from which they were taken. When a larger number of analyses have been made, showing the composition of

these rocks as a whole, it is possible that they can be divided into more than one species. As the analyses stand, the rock is composed of iron, either native or combined, with or without varying amounts of nickel, cobalt, tin, copper, sulphur, titanum, phosphorus, silica, graphite, etc. The specific gravity is high. The presence of graphite shows that it is not of organic origin in this case.

Many of the so-called meteoric irons are probably of terrestrial origin, and their environment ought to be carefully studied. The Wiedmanstattien figures are in some measure paralleled by the leucoxene and cleavage structure of titaniferous and magnetic iron in diabases, etc.

The name 'siderolite' was formerly given by Maskelyne to the species to which G. Rose had previously given the name 'pallasite'; hence, since the latter has the prior right, it is hoped that Maskelyne will allow the transference of the term 'siderolite' as his own, to this species, to which it most properly belongs, since its individuals are emphatically rocks of iron.

2. *Pallasite.* — This species is formed from a series of rocks of like origin to the preceding; and the structure is that of a sponge- or semi-sponge-like mass of iron, either native or secondary, holding silicates. The iron has the associations usual in siderolite; and this association holds good wherever the iron occurs in meteorites, and probably on more careful study will be found to hold good, to a great extent, in terrestrial rocks. The silicates are principally olivine alone, or in association with enstatite and diallage. More rarely feldspar and other silicates occur. There are but two or three complete analyses of the pallasites that can be regarded of value; Joy's [*Amer. journ. sc.*, 1864 (2) xxxvii. 243–248] being the best yet made. The silica increases in amount, up to some 30%, averaging about 20%, with variable quantities of magnesia, rarely exceeding 24%; while the remaining constituents are chiefly iron and its associates. Specific gravity less than in the siderolites.

Under pallasite are classed the supposed meteorites of Atacama, Bitburg, Brahin, Breitenbach, Krasnojarsk, Potosi, Rittersgrün, Rogue River, Sierra de Chaco, Singhur, and more doubtfully those of Hainholz, Mejillones, and Lodran. Of terrestrial rocks under the pallasites belong the olivine-magnetite rocks of Cumberland, R.I., and Taberg, Sweden; for which, as a varietal form, I would propose the name 'cumberlandite'. It is probable that many other pallasites will be found on careful investigation of the iron-bearing rocks. Some schistose rocks (actinolitic) are probably the result of the extreme alteration of the cumberlandite.

The Ainsa and Carlton meteorites from Tucson have a fine sponge structure, and contain numerous olivine (?) grains; but, although they approach the pallasites, they have been classed with the siderolites.

3. *Peridotite.* — This term, applied by Rosenbusch to the pre-tertiary terrestrial olivine rocks, I would extend to all terrestrial rocks and meteorites of a similar composition, — including every thing from the pallasites to the basalts. These rocks are composed principally of silicates and iron; the former preponderating, and the latter sometimes wanting. The silicates are principally olivine, enstatite, and diallage or augite, and sometimes feldspar. The iron is either native, or in the form of pyrrhotite, magnetite, chromite, etc. Silica and magnesia are more abundant, as a rule, than in the pallasites, and less so than in the basalts, while the iron is less than in the former. The specific gravity is also intermediate between the two above-mentioned species.

If it is desired, similar varieties can be pointed out in the meteoric peridotites as in the terrestrial forms; as, for instance, dunite (Chassigny), olivine-enstatite rock (Iowa Co., Knyahinya, Gopalpur, Lancé, Tourinnes, Waconda, Goalpara), lherzolite (Pultusk, Estherville, New Concord, etc.). Also, if desired, an olivine-enstatite-augite division can be made (Tieschitz, Hungen, Grosnaja, etc.).

While part of the meteoric peridotites are entirely crystalline, e.g., Estherville, the great majority are not so, but chondritic in structure. The chondritic structure I believe to be caused by the rapid solidification and arrested crystallization of the masses composed of minerals naturally taking a more or less rounded form; and not from mechanical action, as has generally been claimed. These chondrae show, as a rule, a light or dark gray finely fibrous or fibrous-granular base and semi-base, answering to the globulitic base of the basalts or the felty base of the andesites. This base has heretofore been described as a flocculent opaque-white material, a cloudy substance, the comminuted material, the feldspathic material, etc. Sometimes it is isotropic; but more commonly it affects polarized light according to the amount of olivine or enstatite granules formed in it. When crystallization goes far enough, these granules form by their union the enstatite and olivine grains and crystals.

The base united with the olivine or enstatite gives the structures which have been taken by Drs. Hahn and Weinland as of organic origin. I should expect to find the chondritic structure in terrestrial peridotites, if any can be found in which the crystallization had been arrested and subsequent alteration has not taken place.

The difference in structure between the rapidly solidified, or chondritic, and the crystalline peridotites is not any greater than that between the tachylitic, basaltic, doleritic, or diabasic state of the basalts.

All serpentines not veinstones, which have been carefully studied, appear to belong to peridotite, as a variety produced by alteration.

4. *Basalt.* — To the basalts I should assign such meteorites as those of Jonzac, Stannern, Constantinople, Petersburg, Juvenas, Shergotty, Charkow, Frankfort, Shalka, Massing, Busti, Manegaum, Ibbenbüren, etc., so far as their characters are at present known. These have a lower specific gravity than the preceding, a higher percentage of silica, less iron and magnesia, but more lime, and usually more aluminia.

Some of these meteorites, like the Shergotty and Manegaum ones, are apparently allied to the gabbro variety of basalt.

Beyond the basalts are a few imperfectly investigated forms, which, in the majority of cases, are regarded as doubtful meteorites, which appear to belong to the trachytes and rhyolites, but which require to be studied microscopically before definite statements can be made. Of these forms are some described by Shepard, Silliman, and Grewingk. The carbonaceous meteorites have been too little studied to be given a definite position yet; but, excepting the carbonaceous matter, they chemically appear to belong to the peridotites, although it is not improbable that they belong to a distinct species.

So far as studied, I would class the meteorites, the original and eruptive rocks, under the following species: 1°, siderolite; 2°, pallasite; 3°, peridotite; 4°, basalt; 5°, andesite; 6°, trachyte; 7°, rhyolite; 8°, jaspilite.

If further study shows that other species are needed, then the signification of any of the groups from which the new species are taken can easily be narrowed. As many varietal names can be employed under each species as the needs of the science may demand; but they should be as few as possible, and should hold the same relation to the species that the varietal names of quartz hold to the mineralogical species quartz.

This classification is intended to indicate the probable arrangement of materials in the earth from the interior outwards, beneath the sedimentary formations, as well as to connect, as far as possible, the sedimentary rocks with those from which they were derived.

Meteorites show, to my mind, characters indicating that they have been derived from a hot, liquid mass, and not from any gaseous or solid body, so far as concerns the portion they come from. Of all suggested sources, the most probable one is the sun, provided the eruptive activity now observed on his surface is sufficient to hurl such materials into space; if not now, in past times, when such action was more powerful; or else bodies of similar nature. Meteorites, as far as I have studied them, show no fragmental or tufaceous character beyond such as would be formed by hot, plastic drops falling into a liquid mass of the same material.

They also show that they have not been formed in a locality where life could have existed; for, in that case, the readily alterable materials of which they were composed would have suffered change. M. E. WADSWORTH.

MOLLUSKS OF THE FAMILY COCCULINIDAE.

EXAMINATION of specimens of a Cocculina or an allied genus of that family, from the north Atlantic, shows some remarkable features. These mollusks, recently discovered by the U. S. fish-commission in the deep sea, are most nearly related to the keyhole limpets (Fissurellidae). The specimens obtained by Prof. Verrill, and examined by me, were, however, all females. A number of specimens, of another species, sent me by Dr. Jeffreys for examination, contained individuals of both sexes; and the males were found to possess a verge, permanently exserted from the inner side of the right tentacle. This is a feature hitherto entirely unknown in the order to which they belong, none of the littoral forms of any of the families possessing any such organ; though, like other limpets, dioecious. It is of course probable that the species of Cocculina found by the fish-commission and Prof. A. Agassiz agree in this character with the form from the north Atlantic, about to be described by Dr. Jeffreys; but the latter shows other differences which may require it to be subgenerically separated from Cocculina proper, though evidently a member of the same family. WM. H. DALL.